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XXII.—*The Physical Agents of Temperature, Humidity, Light, and Soil, considered as developing Climate, and in connexion with Geographic Botany.* By Richard Brinsley Hinds, Esq., Surgeon R.N.

It is our present intention to institute some inquiries into the circumstances of climate and physical agents in connexion with the distribution of the vegetation of our globe; and as these are the results of several agents acting in co-operation as well as individually, and their mutual influence embraces much complexity, it will be advisable to regard them separately under the heads of, 1. Temperature, 2. Humidity, 3. Light, 4. Soil.

I. Temperature.

Climate is the great presiding agent over the flora of the world, and, as modified by external circumstances, stamps its characters on the productions. Climates vary a good deal in circumstances, according to the latitude. In the belt which borders on the equator, and is confined within the tropics, the annual climate is of the simplest kind, and is divided into a wet and a dry season. The temperature throughout the year varies but little, and a very trifling range takes place in the barometer. The seasons alternate with surprising regularity, the inhabitants looking forward to the accession or departure of the rains almost to a day. In receding north and south from the equator, the wet and dry seasons take place at different periods of the year; when the sun enters the northern hemisphere, the wet or rainy season of that side commences, and it is then the time of the dry season in the southern hemisphere. The reverse happens as the sun occupies the other side of the equator. Thus two tropical climates exist, very similar to each other, and chiefly differing in the circumstance that the seasons occur at opposing periods. These are the outlines of tropical climates as existing over continents; some modifications take place over the large oceans. Near the equator, and to about 7° N. lat., a peculiar region exists; the trade winds do not advance so far, and light baffling winds, with storms and heavy rains, are the prevailing climate throughout the year. Beyond this, and extending a few degrees outside the tropics in both hemispheres, the trade winds blow; they are remarkable for their regularity, uniform temperature, and general absence from rains.

The tropics ceasing at 23° 28′, another change occurs in the disposition of the year, extending to the thirty-fifth or fortieth parallel. There are now two dry and two wet seasons. The wet seasons occupy the periods corresponding to our spring and autumn. The former is usually trifling, and the autumnal fulfills the chief duties of the rainy season. Towards the limits of this subtropical climate frosts are not unfrequent, but snow is rarely observed. From 40° to 60° four regular seasons rule the year, familiar to us under the divisions of spring, summer, autumn, and winter, each possessing its peculiarities.

Beyond the sixtieth parallel, as far as our knowledge extends, only two seasons exist. These are not characterized by the presence or absence of rain as in lower latitudes, but by the intensity of the range of temperature. Summer and winter succeed each other with singular rapidity. The snow which covers the soil is represented as melting in the short space of fifty or sixty hours, and exposing a vegetation already in its bloom. The intensity of the sun's rays over the temperature of the air is particularly remarkable, and the great length of the day, or, in other words, the continued presence of the sun above the horizon, causes an accumulation of heat, mentioned by our northern voyagers as excessive. Hail is here unknown.

Malte-Brun enumerates nine circumstances as developing climate, the whole of which tend to influence the temperature. If the globe presented an uniform surface throughout, consisting of the same material, and equally reflecting, absorbing, and radiating heat, the distribution of the temperature, from the equator to the poles, would advance in regular progression; but there is such variety in the arrangement of land and water, elevation of surface, and in the investing productions, that every spot displays an union of causes, militating against a regular distribution of temperature.

The most natural view to be taken of climate will regard the relative distribution of temperature and moisture; for though several other agents are subservient, these two will constantly be found to preside*. In this manner it will be easy to sketch

* The subject of the Distribution of Temperature on the surface of the Earth has been elaborately investigated by Professor Dove of Berlin in two works published in 1840, 1841. abstracts of which by H. Croft, Esq., will be found in Part X. of Taylor's 'Scientific Memoirs.'—Ed.

out a number dependent on the proportionate influence of these agents, and the prominent climates of many parts of the world may be shortly and effectively expressed. This method is entirely independent of latitude or geographical position, and refers solely to the condition of the climate as it actually exists, depending on local influences. Sixteen climates of this kind may then be formed, each of which is easily expressed, and, from the examples adduced it may be stated, coincident with a peculiar vegetation.

Climates.

Mean temp. 70°—84°.

Hot and dry climate; seasons in extremes, ex.
Hot and dry climate; seasons even, ex. Arabia.
Hot and moist climate; seasons in extremes, ex. China.
Hot and moist climate; seasons even, ex. Malay islands.

Mean temp. 55°—70°.

Warm and dry climate; seasons in extremes, ex. Asia Minor.
Warm and dry climate; seasons even, ex. Egypt.
Warm and moist climate; seasons in extremes, ex. Southern States of America.
Warm and moist climate; seasons even, ex. Canaries.

Mean temp. 45°—55°.

Temperate and dry climate; seasons in extremes, ex.
Temperate and dry climate; seasons even, ex.
Temperate and moist climate; seasons in extremes, ex.
Temperate and moist climate; seasons even, ex. England.

Mean temp. 45°—32°.

Cold and dry climate; seasons in extremes, ex. Canada.
Cold and dry climate; seasons even, ex.
Cold and moist climate; seasons in extremes, ex. Siberia.
Cold and moist climate; seasons even, ex. North of Scotland.

There is, however, in spite of all local causes, a certain relation between the temperature and the latitude; from the equator to the poles a gradual decrease takes place. Rather conflicting statements have been made respecting the mean temperature at the equator. Mr. Atkinson has fixed it as high as 86°·55, which is certainly in excess; Mr. Kirwan gives 84°; Sir John Leslie 84°·2; Mr. Forbes 81°·5; and Humboldt also 81°·5. The latter have been considered as too low, but the last-mentioned authority continues to maintain his original opinion. I was induced to consider, that in the absence of a regular series of observations, the mean heat of the day, when the sun was in or near the zenith, would at least give the possible extreme of the greatest annual mean heat. From observations on two occasions, I found the mean to be 81°·9; and as this result was obtained at sea and under unexceptionable circumstances, it tends strongly to support the opinion of Humboldt and Forbes. Within the tropics the mean temperature is everywhere very similar, distance from the equator exerting a very feeble influence. After passing their limits, latitude is of greater importance, and the decrease more rapid. If implicit confidence can be placed in the details of the calculated table of Sir John Leslie, the mean temperature varies most with the parallel, between the thirtieth and fiftieth degrees. Though this table cannot be relied on for ascertaining the mean of any given place, it is yet highly useful in showing its value in any situations removed from disturbing causes; and we discover the importance of these last in the difference between the observed and the calculated result.

If some difficulty has been experienced in fixing the mean temperature at the equator, we are much more at a loss at the poles. No navigator has ever yet made, or perhaps ever will have it in his power to make, a conclusive series of observations to establish the point. Conjectures, drawn from observed temperatures in lower latitudes, are all we possess at present, and these are at great variance. Sir John Leslie considers it to be 32°, or the freezing point of water; Kirwan places it a degree less; Mr. Atkinson, who seems partial to extremes, at 10°·53 below the zero of Fahrenheit. Inferring its amount from the temperature of the old world, it appears likely to be about 10°; whilst corresponding inductions from the new world place it considerably below zero. M. Arago has given the subject his attention, and after comparing the observations of Parry, Franklin, and Scoresby, he fixes it at 13°. Here, then, we have various opinions, which state a set of means having a range of forty-two degrees and a half. Among such conflicting statements every one will desire to judge for himself; and the following observations, the first by Franklin, and the others by Parry, may be of some assistance. They may be considered as intervals of five degrees:—

Fort Enterprise	Lat. N. $64\frac{1}{2}$°	Mean temp. 15°·5
Igloolik	... $69\frac{1}{3}$	 7
Melville Island	... $74\frac{3}{4}$	... ... −1·5

It is not unlikely that Sir Edward Parry at Melville Island had attained the greatest depression of temperature, and that had he even been able to reach the pole, the alteration, if any, would have been exceedingly trifling, the arctic regions, like the tropics, through their extent, most probably offering no great variations. Recently an opinion has been advanced, that the greatest cold is not to be found in the vicinity of the poles. It is supposed that a centre of greatest cold may exist in each of the continents of Asia and America, a theory founded on the well-known cooling effects of all large masses of land in high latitudes.

The information conveyed in a knowledge of the mean temperature* is very slender. Standing alone, it gives no idea of the distribution of heat throughout the year. Indeed it must be confessed, that a complete acquaintance with the vicissitudes of any one spot, during twelve months, embraces a considerable number of details. When acquainted with the mean heat, the chief point gained is an idea of the situation of any particular place on the globe with respect to latitude; our previous knowledge fills up an outline of the climate. By no limited number of facts can much desirable information be conveyed. Perhaps the most complete will be obtained in an expression of the annual range of temperature. Even this will often be found not very satisfactory.

The range of temperature throughout the year, like the annual mean, bears a certain relation to the latitude. In low latitudes the range is comparatively small; in high it is often very great. Near the equator, and within the tropics, the range of heat is very trifling; here the changes of a day are almost those of a year. For some hours after the disappearance of the sun's rays, the temperature falls but little; during the night gradual depression goes on, and a little before sunrise it has reached its maximum. At this time the thermometer will stand from 15° to 30° lower than in the hottest period of the day. This depression, though comparatively small for its effects, has a marked influence on animated nature; not only do the inhabitants of these warm climates complain of the coldness of the atmosphere with the thermometer at 65°, but domestic animals and the birds of the forest are evidently much disturbed by it. The effects are but short, the sun rises rapidly above the horizon, and the period of excitement and of powerful heat again returns. It is most probably owing to the exhausting power of the sun's heat and

* Some rapid methods have been recommended to obtain the mean temperature, where the more lengthened processes were impracticable. The mean of the day may be found by meaning three observations made, just before sun-rise, at 2 P.M., and at sun-set. Annual means for the latitude correspond with the temperatures of considerable depths, as at the bottom of the shafts of mines, and in wells. In the tropics, Boussingault advises the sinking of a thermometer a foot below the surface of the soil, where it is constantly shaded by a roofing. He mentions particularly the belt between 11° N. lat. and 5° S. lat. as suitable. In our parallel, the mean of the month of October is said to be very near the annual mean.

light during the day, that this small decrease of temperature is so keenly felt.

Range of temperature is also much affected by local causes, as the vicinity of forests, sandy plains, and mountain ranges, which elevate or depress the sensible heat. In the northern regions a high temperature is accumulated by the continuance of the sun above the horizon, and correspondingly depressed in its absence; but on other occasions the range will be found to increase as the mean temperature diminishes. At sea the range is much smaller than on land, attributable to the equalizing power of the ocean. In the trades there is scarcely a variation of a few degrees in twenty-four hours; in higher latitudes it is greater, but is perhaps not more than half what it would be on the land.

In the subjoined table, the relation of the range of temperature to the latitude and the mean heat is shown. The agency of local causes is also visible in the great range at Astrakan in proportion to its mean heat; and again at Sidney compared with the Cape of Good Hope, both in nearly the same parallel:—

Sandwich islands...	Lat. 21°	40′	N.	Mean temp. 75°	Annual range 29°
Sidney	33	51	S.	 70	 79
Cape of Good Hope ...	33	56		... ... 67·5	 51
Columbia River	46		N.	 54	 74
Astrakan	46	21		... ...	 130
London	51	31		 51	 79
Kinfauns	56	23		 47	 58
Greenland				... ...	 138

The highest temperature ever recorded to have taken place occurred in Africa; here, at Fezzan, it was observed on one occasion to be 125°·5, and at Belbeis in Egypt 125°; both these are supposed to have been produced by a wind carrying minute particles of heated sand from the desert*. Under these circumstances Humboldt saw it at 114°·5 in South America. In August, at Bagdad, the thermometer has been known to reach 120°. Dr. Heberden witnessed the highest temperature in England, when, in the month of July, the thermometer stood at 98°. Sir Edward Parry has observed the greatest excess in the other extreme; at Melville Island, in the month of February, the cold was so intense, that the thermometer descended to 55° below zero. Several observers have likewise seen mercury freeze in the northern parts of America and Asia, which requires a depression of 72° below the freezing point. It so happens that this range of excesses is exactly equal to that between the congelation and boiling

* On more than one occasion I have known the sand near the sea-shore, supporting an appropriate vegetation, heated to 128°.

of water, or 180°. These extremes of temperature for the surface of the globe are indeed great, and they demonstrate how wonderfully man is capable of adapting himself to circumstances, as beneath each he is able to exist; nor does there appear any reason why the vegetable kingdom should not thrive beneath the same. Some persons, for experiment, have exposed themselves to a greater degree of heat, and without unpleasant results; but this was only for a certain time, and gives no idea of the effects of an habitual exposure to such excitement.

Observations on the condition of organized nature in the hottest regions of the world will lead us to the conclusion, that there is an intimate adjustment between the productions, animal and vegetable, and the agency of external causes. If the temperature were by any unforeseen circumstances to be raised a few degrees, a corresponding change in the temperament and organization of the living beings would be necessary for the proper fulfilment of their functions. A comparison of different latitudes with each other, and the allotted productions of each, clearly manifest the intimate relations between the climate and the vegetation, and the reluctance displayed to leave the conditions under which they have been placed. Many instances might be mentioned to prove, that the exact circumstances acting on the vegetable kingdom are those the most favourable to its existence; it will be enough at present to add, that similarity of climate does always support similarity of productions; that however distant the situations may be, wherever similar external causes are active, there we shall find similar states of organization.

There are still some remarkable instances, at times noticed by the naturalist, which demonstrate that vegetation does thrive under unusual conditions. These cases are exceptions, but not less interesting on this account, and show to what extent the organs of plants can modify their functions under the influence of unnatural circumstances. At present our attention is confined to temperature, and many curious facts have been noticed of plants appearing to thrive well in situations where the surface has been heated by internal fires, or actually in hot springs themselves. One of the most interesting, perhaps, of these circumstances is mentioned by Mr. Barrow in his 'Voyage to Cochin-China.' At the island of Amsterdam, he observed a paste near some hot springs, the temperature of which was 186° at eight inches beneath the surface. On the top were growing a *Lycopodium*, a *Marchantia*, and a small delicate moss, being members of three natural families, but all agamic. In a hot spring at Gastein, with a temperature of 117°, *Ulva thermalis* was found growing. James, in the expedition to the Rocky Mountains, relates seeing Conferva and "other vegetables" growing in the numerous thermal springs at the base of the Ozark mountains, with the temperature from 92° to 140°. The last two instances are not, however, very remarkable, when we call to mind the heat to which vegetation is exposed in low latitudes from the direct power of solar radiation. Sir W. J. Hooker has supplied us with some very interesting facts respecting the vegetation near hot springs in Iceland, and especially the Geysers, the temperature of which is equal to boiling water. On a heated bank where they were exposed to the steam, *Conferva vaginata, Gymnostomum fasciculare, Fissidens hypnoides,* and *Jungermannia angulosa,* flourished in the greatest perfection. At the Geysers, "close to the edge of many of the hot springs, and within a few inches of the boiling water, in places which are consequently always exposed to a considerable degree of heat, arising both from the water and the steam, I found *Conferva limosa.*" In a similar situation, an *Oscillatoria,* and *Jungermannia angulosa.* Again, in water of a "very great degree of heat," *Conferva flavescens*; and another species, *Riccia glauca,* was also found on a surface considerably heated. All these plants, excepting the doubtful expression of James, belong to families of the simplest structure, and whose members have the widest geographic limits; among plants they appear those least affected by extremes of temperature.

Plants of more complex organization have likewise been found in similar situations, but not with the habitual frequency of the agamic families. The thermal springs of Trinchera, near Valencia, have a temperature as high as 194°; vegetation of surpassing luxuriance surrounds them, and the roots of species of *Mimosa, Clusia,* and *Ficus* are bathed by their waters.

Under opposite circumstances vegetation hardly thrives so well, still it is capable of enduring great depressions of temperature*. Thermometers placed in the trunks of trees have stood below the freezing point. In the arctic regions flowers struggle through the melting snows, and one plant has its existence even in the snow itself, where it vegetates, reproduces its species, and decays. *Protococcus nivalis* has been found in the snows of the arctic regions, among the Alps and Pyrenees, and in other situations in Europe; of late years it has also been observed among the islands to the south of Cape Horn. In low latitudes plants are often subject to an unexpected depression; I have already mentioned casually

* This subject has lately been treated of by M. Morren. See 'Observations Anatomiques sur la congélation des Organes des Végétaux.'—Bulletins de l'Acad. de Bruxelles, t. v. p. 64.—Ed.

how far this obtains in the tropics, and a further decrease must be allowed for nocturnal radiation. Mr. Daniel has made us acquainted with the unexpected circumstance, that in our own climate, vegetation, in ten months of the year, is subject to a temperature below the freezing point. Even in the two months which are exceptions, July and August, the thermometer exposed to terrestrial radiation sometimes sinks to 35°.

Cultivation has been always allowed to have a material influence on the temperature, but as people formerly were much less curious on the subject than at present, it is almost an impossibility to obtain correct data. Even the few years that have passed, since the reclaiming of the land in many of our colonies, had their commencement at a period when registers of daily fluctuations in the thermometer were overlooked, among the claims of more important pursuits. The effects must of course vary according to the circumstances of a tract of country previous to its being submitted to cultivation. Deep impervious forests are frequently removed by the diligence of the settler, and a new and perhaps extensive surface exposed to the direct action of the sun and air. The changes which follow here must be very different from those occurring over another space of country, where cultivation, instead of circumscribing the reign of the vegetable kingdom, continually adds to it.

To place these opposite conditions in a clearer light, we will select two instances, and by detailing the chief peculiarities of the climate of each, may be enabled to draw a satisfactory comparison between them. The island of Ascension is almost destitute of vegetation; in the sheltered ravines and temporary water-courses of the rainy season, a few ferns and other plants thrive. Their number is small, and the soil almost everywhere without a flora. The climate, however, is delightful; it is rather warm, but very healthy. In the hot season the thermometer only ranges ten degrees in the twenty-four hours, and during the time of the rains only eight. The whole range of the year is not more than sixteen or eighteen degrees. Rain is scarce even in the proper season, a circumstance always occurring in similar situations, and dews are also far from frequent; indeed the small depression of the temperature during the night can seldom be expected to reach the point of deposition. Very different conditions will be found in that part of North America which comprehends the Canadas and the northern portion of the United States. This is truly a climate of extremes; the winter is intensely cold and protracted, snow lying long on the ground; when summer succeeds, it is to run into the opposite excess of oppressive heat. The changes from heat to cold and *vice versâ* are extremely rapid, so that the spring and autumn to be expected in these latitudes are obliterated in the rapid transitions of summer and winter. The climate has not been found particularly healthy, arising, no doubt, from the exposure in the clearings of a soil containing much vegetable matter in decomposition. Vegetation is very active; immediately on the breaking up of the winter the trees put forth their buds, and herbaceous plants spring rapidly into existence. Some little cultivation is now taking place at Ascension, which is yearly increasing; about fifty acres have been broken up, and small as the quantity is, a notable change is said to have been produced by it on the climate. Rain is become more frequent than formerly; and though there is no mention of the altered temperature, the circumstance of an increased deposition of moisture bespeaks a change in the range of the thermometer. In Canada it is also generally allowed, that the climate has become milder since the disappearance of the forests from any extent of surface.

Many instances might be mentioned where the removal of forests has greatly lessened the quantity of rain; and every one of the West India islands would furnish examples, with the consequent disappearance of streams and mountain-torrents. Supposing the circumstances of evaporation to remain the same,—and surely the removal of vegetation is not likely to increase it, rather the contrary,—the only cause to which the greater rarity of rain is attributable, is the higher standard which the low ranges of temperature have taken. In Europe, where cultivation has been very extensively practised, the climate is certainly warmer than formerly; and if we trust to the accounts left us by the historian Tacitus of the circumstances of a German winter, the changes have indeed been great. At the present day, in those parts of Europe where forests exist, as in Germany and Poland, their influence is distinctly felt. In their vicinity the harvest is not so advanced by several days, and a corresponding decrease of temperature is noticed.

Among the controlling causes of temperature, the relative distribution of land and water is not the least important or interesting. In the ocean originate the peculiarities of an island-climate, conferring an atmosphere laden with moisture and limited in its range of temperature, and forming a subject of great attraction to the geographic botanist; its influence over continents is also great. We trace its outline into deep gulfs and seas, separating large masses of land from each other, and sweeping around them so as to expose their coasts to its humid atmosphere and winds. We can hardly contemplate this arrangement without acknowledging a particular object was to be obtained. Perhaps on this account it is that it has always required rather a fanciful imagination to discover that the continents and mountain ranges pursued a direction, having a general connexion with the cardinal points. The influence of the surface of the ocean will depend on the previous temperature; thus in low latitudes, where the temperature is great, the former is constantly active in depressing it. Sea-water rarely attains upwards of 86°, and the atmosphere over it 88°; as this latter is surpassed over the land, its depression at sea is solely attributable to the equalizing power of the surface of the ocean. The air also during the night undergoes very small changes of temperature; and should there be any disposition to a considerable fall, the surface of the water is always ready, as a compensating agent, to part with its heat to the cooling atmosphere. On this account the island-climates of these parallels are not subject to such high mean or daily temperatures as continents, and the range is less extensive. The agreeable influence it has is sufficiently prominent, and continues the same as we traverse higher latitudes; but its power of cooling the air gradually disappears, till it entirely ceases between the twenty-fifth and thirty-fifth degree, the exact spot fluctuating with the season of the year. An opposite effect now commences; the ocean, instead of cooling, parts with heat and elevates the temperature, whilst its power of curtailing the range remains the same. Island-climates have now higher annual and daily means, and are equally preferable as protecting us from the disagreeableness of another excess.

The conditions of an island-climate of this kind are visible over a very large portion of the continent of Europe, where its peculiarities are often developed. A comparison between its productions, and similar parallels on the continents of Asia and America, will soon satisfy us as to this circumstance. In Europe where the oak, ash, beech, and elm thrive, there are in America gloomy forests of fir and cypress. At Nootka Sound, in the western or warmer coast of America, and in a lower latitude than London, a dense forest invests the surface, consisting of species of *Abies*, *Cupressus*, *Betula*, and *Cerasus*, with shrubs of *Ribes*, *Rubus*, *Rosa*, *Vaccinium*, and *Andromeda*. Barley and rye are cultivated in Europe within the arctic circle, and forests of *Pinus sylvestris* reach to the extremity of the continent. Nothing like this occurs in America, where we find instead a scanty vegetation of lowly bushes of *Salix*, *Juniperus*, and *Betula*. At San Francisco in California, in 38° N. lat., the open forest of this fine country is composed of trees of *Quercus*, four species, two deciduous, two evergreen; *Fraxinus*; *Platanus*; *Salix*, several species; *Pavia*; *Populus*; *Betula*; *Juglans*; and often an abundant undergrowth of various shrubby *Compositæ*. *Pinus rigida* grows at the level of the ocean, and *P. religiosa* on the elevated land. In Europe we can ascend several degrees of latitude higher and still be surrounded by a milder vegetation, though the Alps present a natural and stupendous barrier to the diffusion of the southern flora. The vegetation is everywhere open, and large trees unfrequent; its larger members belong to *Quercus*, several evergreen species; *Phillyrea*; *Buxus*; *Cistus*, numerous species; *Pistacia*, and *Paliurus*. The ash meets too warm a temperature below 41°; oranges and olives are cultivated in great abundance. *Chamærops* has in Europe a representative as far north as 44°, whilst on the eastern coast of North America a near relative is limited to 36°. Some species of *Pinus* are found throughout Spain, and on its Mediterranean shores *P. halepensis* and *P. pinea* flourish.

Asia partakes of the features of America in a comparison with Europe. *Quercus robur* ceases 2° further south, and grows but sparingly below this. Barley is not cultivated nearly so far north as in Europe; *Pinus sylvestris* does not venture near the arctic circle, and many of the forest trees common to both are all more or less circumscribed by a less favourable climate. Towards Europe the vegetation of Asia becomes imperceptibly blended with that of the former. In the north-west part of Europe the climate is severer, and resembles closely the Asiatic; on this side it is invested by mountain ranges, and the cold winds blowing from them are piercing, and contrast strongly with the hot winds of the south, and the moist westerly breezes from the Atlantic Ocean.

The disparity in the temperature of the northern and southern hemispheres also originates in the equalizing power of the ocean. In the southern the proportion of water to land is greatest; within the tropics there is no great difference, but beyond them it becomes important, and as there is here no great extent of dry land, the climate possesses in many respects the character of an island-climate. To say that one hemisphere is hotter or colder than the other, is not expressing the actual condition of either; one possesses a continental climate, or a climate tending to extremes; the other an island-climate, or one limited in its range of temperature. The summers of the extra-tropical regions of the southern hemisphere are not so warm, nor the winters so cold, as in the northern; yet the total amount of the mean maximum temperatures of each throughout the year would in all probability be very similar. Under these conditions vegetation appears not to thrive so well as where the seasons are subject to extremes: thus the southern lands are almost destitute of a plant where the north of Europe supports a tolerable vegetation.

Along the margins of continents there are portions of the surface which experience the effects of the ocean, whilst beyond this in the interior a continental climate is retained. These strips have a modification of climate holding a station between continents and islands: their temperature is of course governed by the region of waters flowing around them, and are also exposed to vicissitudes from the interior. Mr. Kirwan has made an estimate of the progression of temperature in these cases; for every fifty miles from the sea he states the annual mean to be affected according to the latitude as follows:—

From latitude	70° to 35°	cooled	$\frac{1}{3}$	of a degree.
...	35 ... 30	...	$\frac{1}{8}$	...
...	30 ... 25	warmed	$\frac{1}{3}$	...
...	25 ... 20	...	$\frac{1}{2}$	...
...	20 ... 10	...	1°	

Malte-Brun, though he has treated the effects of aspect with considerable happiness, has hardly distinguished the influence of the direction of a surface, apart from its inclination, with sufficient accuracy. Aspect expresses the direction of a surface in regard to the sun; to have a good aspect is to hold one opposite to its midday rays. At the same time, inclination of surface must not be overlooked, for presently we shall show that it materially influences the temperature. Every mountain range displays a crowd of instances of its effects on the vegetable kingdom, on the habits of animals, and the migration of man. To prevent any unnecessary repetition of words, we shall confine our attention to the circumstances of inclination and direction of surface in the northern hemisphere; and on reconsidering this subject in the southern, the same causes will be found active, with the only necessary allowance for the opposite situation of the sun.

A mountain may be imagined with four sides, the direction of whose aspect is such that they regard the four points of the compass, east, west, north, and south. Suppose, further, that these sides have a regular slope or inclination, which we shall place at 45 degrees. At sun-rise in the morning the rays of heat will strike on the east side, making an allowance for the sun's rising a little to the south of true east. They will act but feebly, both from the cool air they have to traverse, and from the very trifling elevation of the sun, this latter circumstance causing them to arrive at a very unfavourable angle. The sun gradually reaches the southern side, and continues to ascend in its course. The surface becomes warmed, heat is imparted to the atmosphere, and they continue to receive warmth till some time after midday. The eastern side, however, is momentarily less exposed, and those it has received have been only the cooler rays of the morning, whilst the west is gradually becoming bared to the sun, after it has attained its meridian height and power, and the surrounding objects are all well warmed. Hence we perceive the advantage of a southern aspect in the northern hemisphere, and the superiority of a west over an east. We have supposed the sides of the mountain to have an inclination of 45°; if the meridian elevation of the sun only attains 30°, we shall have its rays impinging at an angle of 75°, and one capable of imparting very considerable warmth. By substituting any known mountain, and converting our plane sides into the customary irregularities and depressions, valleys and ridges, the great advantages of aspect will be more manifest, especially after watching the daily passage of the sun over it, and gaining an acquaintance with the vegetable productions.

Were it not for the atmosphere, the temperature throughout the day would follow the different dispositions of the sun with regularity. Instead, however, the early sun gives out very little sensible warmth, its real heat being absorbed by the atmosphere after its reflection from the surface of the earth. Even at midday, when it might be supposed that the sun was diffusing most heat, the temperature of the air has not reached its maximum. The time of this varies with the latitude between the hours of 1 and 3 P.M. In the afternoon, when the air is thoroughly warmed, and the sun approaches the western skies, the warmest portion of the day has arrived, and the atmosphere retaining the heat with some tenacity, the subsequent depression of temperature takes place slowly. Every one must at times have felt the power of the declining sun's rays through a heated atmosphere when they fall on the uncovered parts of the body. This different diffusion of apparent heat, at periods when the sun holds similar situations with regard to the earth, has its effect on aspect, and bestows some superiority on a position exposed to the afternoon's sun; thus somewhere between the south and west points will be found preferable; the mean, south-west, is perhaps the best; in low latitudes approaching a little to the south, and in high to the west. It is due to the superiority of the south-west aspect that Madeira is able to produce its Malmsey and Cercial wines, for it is on this that the vine which yields them is alone cultivated.

To ascertain the value of this varying intensity, I took the opportunity of the sun being very near the zenith to make the observations contained in the table.

Macassar, lat. 5° 8′ S., September 30th.

Time.	Sun's Altitude.	Temp. of Shade.	Thermometer. Vertical.	45°	Horizontal.	Remarks.
A.M. 9	45° 15′	80°	104°	108°	102°	The three thermometers placed in the sun had their bulbs covered with cotton blackened with Indian ink. A sea-breeze throughout from the westward, slightly increased about midday.
... 10	61	82	105	111	108	
... 11	74 20	82	101	106	109	
... 12	87 40	83	97	100	113	
P.M. 1	74 20	85	95	100	109	
... 2	61	85·5	93	101	105	
... 3	45 15	84·5	91	96	101	
... 4	29	84	91	92·5	93	

Perhaps the results of these observations are not altogether what might have been anticipated; they will however show incontestably the advantage of an inclined, or even of a horizontal surface over a vertical one, when the altitude of the sun is great. To convey an idea of the customary range of the sun's altitude in the latitude of London, I add it on four astronomical periods.

	Sun's meridian altitude.		
March 21, vernal equinox	38°	41′	40″
June 21, summer solstice	62	8	43
September 23, autumnal equinox .	38	41	14
December 21, winter solstice . . .	15	13	14

Our attention is now requisite on the north aspect. The long deep shadows which attend this position on the rising or setting of the sun are strongly characteristic of mountain scenery. In the evening, long before the sun approaches the horizon, the vegetation is plunged in shade, whilst the opposite side, perhaps of a fertile mountain valley, still lies exposed to its warm beams. The direct action of the sun, or the power of solar radiation, over the vegetation is much below the average. Inclined surfaces at an angle of 45° are far beyond what are usually found supporting a rich vegetation. But taking half this amount, it will require a greater altitude than is experienced by us during a portion of the year to relieve it at all from the shade. It is not then surprising that chains of mountains will offer a difference of thousands of feet on opposite flanks, in the limits of cultivation, or the growth of members of its flora. In addition to the obliquity of the sun's rays, when they really do reach the flora, their visit is for so short a period of the day, that their influence is hardly felt till they are about to disappear.

Some illustrations will show the practical advantages arising from aspect. In the mountains on the borders of Dumfries-shire and Clydesdale, the difference is marked between the north and south faces. In the former the snow often lies on the ground, and the sheep are fed with hay, whilst the flocks on the southern sides still find pasture. Esmark has observed in the Dofrines, that those sides which are exposed to the north and north-east have the snow line at 3000 feet above the level of the sea, whilst on the south and south-east declivities, where the exposure is so much more favourable, it attains an elevation of 7000 feet. In the Valais, one side of the alpine mountains is covered with perennial ice and snow, the opposite supporting a smiling vegetation of orchards and vineyards. Another part of the central Alps has been noticed to produce oats on its southern aspect at 3300 feet, and on the northern they were scarcely growing at 1800 feet.

The Himma-leh mountains offer numerous modifications of climate arising from local causes. Their examination would furnish illustrations of almost all the modifying causes found in the mountain ranges of other parts of the world; not being merely a barrier of elevated land intersecting a large country, but consisting of numerous minor ranges of mountains crowded together, pursuing at times all directions, and presenting all exposures: often, too, at great elevations extensive valleys are displayed, enjoying a climate unusually favourable. Indeed, the space occupied by the Himma-leh mountains embraces a great extent of country, both in length and breadth, as even the most constricted parts are many miles across. The general statement is, that there is a difference of 3000 feet between the two flanks, in the elevation to which cultivation and habitations extend. Though in the northern hemisphere the difference is in favour of the northern side, here corn-fields and the dwellings of men cease at 13,000 feet, which on the south are limited to 10,000 feet. This seems to be the general difference, whilst causes in particular places will be in action to increase or diminish it. Circumstances operating on both sides of the chain have been brought forward, to account for this departure from the usual course of things; one will perhaps be found enough, and it consists merely in the very considerable elevation of the table lands stretching from their northern roots. Immediately bordering the Himma-leh range to the north are the greater and the lesser Thibet, or, as M. Balbi terms them, east and west. He regards them as consisting of two extensive table lands, having the surprising height above the ocean of from 8000 to upwards of 14,000 feet. In addition to this elevation they contain large sandy plains; and the heating of the atmosphere from their burning surface, added to the necessary allowances for elevation, will fully account for the high station cultivation takes on the north flank. It will be sufficient to add, that on the southern side the presence of moisture, and the increased quantity of rain falling over the plain of India, will of course cause a depression of temperature unknown in the transparent and heated atmosphere of Thibet.

Valleys usually enjoy a milder climate than the adjacent country, from the protection afforded them by surrounding eminences. Some of those among the Himma-leh mountains on the Indian side have a vegetation hardly to be expected in such situations. The vegetation of the tropics has migrated into them, at elevations of 2000 feet and upwards. In these valleys the advantageous circumstances are, a protection from destructive winds, and an exposure to the warm temperature and copious rains of a tropic, or at least subtropic, climate. Detracting causes will sometimes occur even in valleys; the stillness of the air promotes nocturnal radiation from the soil, and under this heat rapidly disappears. Mr. Daniel on this subject says, "I have seen a difference of thirty degrees on the same night between two thermometers, one placed in a valley, the other on a surrounding eminence, in favour of the latter." The valleys in Switzerland are cold for another reason—the sides are often so precipitous that they are more properly ravines; the sun's rays descend into them only during a very small portion of the day, and the consequence is, the snow line often sinks 2500 feet.

Similar instances of the powerful agency of local causes might be multiplied indefinitely; I shall only give one more, which places it in another point of view, where what at first appears an unfavourable exposure, and what in reality it still continues to be, has enlarged the range of a plant. In many of the alpine valleys of Dauphiné the declivities with a northern exposure are covered with larch; those, on the other hand, with a southern aspect are entirely destitute of them.

Assuming a position at the equator, it will be observed, that a set of phænomena takes place simultaneously in two directions, and with a general resemblance; the one occurs with the latitude, the other with the elevation through the atmosphere. Already the decrease of temperature with the former has been noticed; it remains to speak of a similar circumstance in the latter. Saussure was one of the earliest in noting observations on this subject, and subsequent experience has confirmed their accuracy. Still the differences among observers are even now considerable; and it appears to be a circumstance subject to numerous disturbing agents. The seasons of the year affect it, for in summer Saussure found the thermometer to sink 1° for 292 feet of elevation, whilst in winter it required 419 feet to produce the same. Raymond's observations approach those of Saussure; he found it required 299 feet. Aubuisson gives 315 feet as equal to 1° of depression. Gay-Lussac conducted his observations on a more extensive scale, and in the summer he ascended from Paris to the surprising height of 22,960 feet; for the whole distance 341 feet were found to be equivalent to 1° of the thermometer. As the decrease is now known not to be uniform, and the observations of Gay-Lussac were not made at regular intervals, their value is very trifling. Besides, they were made in open space, and are likely to give a very different result to others made at certain gradations on the slope of a mountain. Some simultaneous observations were made at Geneva and Mount St. Bernard, which give 352 feet.

Observations have not been wanting in the British Isles. From the results it appears, that it requires here a less elevation to effect the same changes in the temperature than on the continent of Europe. Sir Thomas Brisbane and Mr. Wm. Gilbraith found it to be 212 feet in heights of 2000 or 3000 feet. Mr. Hewitt Watson has conducted similar experiments, and has communicated the minutiæ of his proceedings with an unreserve that gives them an additional value. Unfortunately he himself registered the observations at the heights and bases of the mountains, which sometimes embraced an interval of several hours. He also mentions that observations made on the same spot at different times varied considerably, being a confirmation of the opinion expressed above. Several temperatures were registered among the highland mountains; they fluctuated much, and the mean of the whole gave 216 feet for 1°. Further observations, made in Cumberland during warm and dry weather, gave 298 feet; and in Caernarvonshire in cold and moist weather 212 feet. This is the reverse of what Saussure had observed in different seasons.

The observations made on the continent, taken together, will yield a mean of 336·33 feet of elevation for every degree of depression in the thermometer. Those obtained in Great Britain have the mean of 234·50 feet for the same; and the two combined give 285·41 feet. By applying these means as a correction for the elevation of any place where the mean temperature has been accurately observed, and thus finding the mean temperature of the base at the level of the sea, it will only be necessary to compare the latter with the mean temperature in Leslie's table to ascertain their correctness. The Hospice of St. Gothard is fixed at an elevation of 6390 feet, and the mean temperature of the year is 30°·4; with the correction it will be 49° at the base, whilst the latitude of St. Gothard by the table gives a mean of 57°·6. Again, Berne is situated at 1650 feet, and has a mean temperature of 49°·2; the base will be 53°·9 by the correction, and by the table 57°·2. The corrections here applied are from the mean of the European continent, as being the situation both of the experiments and of the examples, and the results can hardly be considered as approximations. With the mean of Great Britain a greater correctness is apparently obtained, making the mean temperature of the bases respectively 57°·7 and 56°·3.

Another illustration taken from an extremely interesting spot will suffice. The city of Quito occupies a plain raised to 9500 feet, and surrounded by numerous volcanoes; among them are Chimborazo, Antisana, and Pichincha, with many others equally stupendous but less known. Its mean annual heat is 67°, and is situated only 13′ from the equator. In this instance we shall use the correction for the height given by Humboldt for the Andes, and take that for the elevation of Quito. This mean, so much above the European, will be mentioned presently; at present we find it to make the base of Quito enjoying a mean of 89°·4. The equatorial mean has been already dwelt upon; and though this surpasses it by some degrees, yet some allowances for the difference will be justified on the same grounds, that the elevated plains of Thibet extend the usefulness of the northern aspect of the Himma-leh mountains.

Thus the decrease of temperature on elevation does not take place uniformly, nor does it occur in the same ratio in the equatorial and in the temperate zones. Humboldt, whose opportunities of multiplying facts at great elevations have been so unbounded, found that the progression was very irregular among the Cordilleras. His observations reduced to English feet stand thus:—

	feet.		feet.	feet.		
From	0	to	3280,	309 are equal to	1°	Fahr.
...	3280	..	6561,	536 ...	1°	...
...	6561	..	9842,	423 ...	1°	...
...	9842	..	13,123,	239 ...	1°	...
...	13,123	..	16,404,	328 ...	1°	...

A comparison of these data with those already given for higher latitudes, will show that diminution of temperature on elevation takes place more rapidly for given distances in the temperate than in the tropic regions. Another table, also constructed by Humboldt, will furnish additional grounds for some conclusive results.

Height in English feet.	Equatorial zone from 0° to 10°		Temperate zone from 45° to 47°.	
	Mean temp.	Difference.	Mean temp.	Difference.
0	81°5	°0	53°6	°0
3195	71·2	10·3	41	12·6
6392	65·1	6·1	31·6	9·4
9587	57·7	7·4	23·4	8·2
12,792	44·6	13·1		
15,965	34·7	9·9		

These are observations for elevations with a rapid ascent, and accordingly having peculiar conditions: another disposition of surface occurs in extensive level countries having only a slight elevation in one or more directions, perhaps rising in a gradual ascent from the sea, or showing an inclined surface to the different points of the heavens; the mean temperature at their sea-level being known, on gradually ascending a decrease will happen; but, as stated by Mr. Kirwan, in different proportions according to the degree of elevation. Taking a height of 200 feet, if the ascent is so gradual as not to exceed six feet in a mile, the diminution in the mean annual temperature will be only $\frac{1}{4}$th of a degree; if 7 feet in the mile, $\frac{1}{3}$rd; 13 feet, $\frac{4}{10}$ths; and 15 feet, $\frac{1}{2}$.

Where observations differ so much, and where those made at one place are at variance with others made under similar circumstances at the same, and even maintain an irregularity through different steps in their ascent, it is impossible to draw any safe practical conclusions. The only plan, where a necessity exists, is to make such allowances as known facts warrant; supposing at the time that it is beyond our power to obtain results for ourselves, and that none have been already made. Within the tropics the table of Humboldt can be used. In the case of Quito we took the mean of its height, and with a success which cannot be considered unsatisfactory. In temperate latitudes the above details will furnish a guide, and also the comparative table of the equatorial and temperate zones. The latter will not be found to deviate much in the warmer temperate climates, but is decidedly too great for higher parallels. Among the colder of these climates a mean of from 200 to 250 feet may be used for a depression of 1° of the thermometer.

[To be continued.]

XXIII.—*Observations on the Progress recently made in the Natural History of the* Echinodermata. By Prof. Agassiz*.

With a view of rendering more complete the results which, in the preface to the first of these Monographs, I have given of my investigation of the *Echinodermata,* I shall here offer some remarks upon the progress recently made in the natural history of this class.

The memoirs which have appeared during several years past, or which are at the present moment in course of publication respecting these animals, are sufficiently numerous. Of these some relate to their classification in general, or to the descriptive natural history of the genera and species; others have reference to their anatomy, both actual and comparative, or it may be that they embrace the study of the numerous fossils which have represented this class at the epochs of the development of organic life. It is in this order that we shall now pass them in review, and in conclusion I shall give some account of the collections which I have lately had the opportunity of examining.

As these different departments of inquiry in the natural history of the *Echinodermata* have advanced rapidly, it is the more to be regretted that a knowledge of their habits, of their alimentation, of their growth, of the functions of their organs, &c., should as it were rest stationary, if we except some detached observations upon the European species.

The only work [among the publications coming under consideration] which embraces the entire class *Echinodermata,* is the delightful volume which Mr. Edward Forbes has published upon the British species (History of British Starfishes and other animals of the class *Echinodermata,* 1840–41). He divides them into six orders:—1st, the *Pinnigrada* or *Crinoideæ*; 2nd, the *Spinigrada* or *Ophiuridæ,* which he subdivides

* From the 'Monographies d'Echinodermes,' No. 2. [We have been favoured by Mr. Charlesworth with the communication and translation of the present article.—Ed.]